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Reply to comment by L. Fenoglio-Marc et al. on "On the steric and mass-induced contributions to the annual sea level variations in the Mediterranean Sea"

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[1] *García et al.* [2006] (hereafter referred to as G06) study the water mass variations in the Mediterranean Sea using a direct and an indirect method. The direct method is based on the gravitational signature of the monthly water mass variations estimated by the space mission of GRACE. The indirect method is as follows: The sea level variation (SLV) is a result of water mass change (SLVmass) plus density variations (SLVsteric). Therefore the residual signal between the SLV (estimated by altimetry measurements) and the SLVsteric (estimated by temperature and salinity profiles from the ECCO ocean model) yields the SLVmass. G06 found a good agreement between the results of the two methods.

[2] However, subsequent similar studies, notably *Fenoglio-Marc et al.* [2006] (hereafter referred to as F06) found different results, which are commented on by *Fenoglio-Marc et al.* [2007] (hereafter referred to as F07). F07 found some differences between G06 and F06 in both SLVsteric and SLVmass signals.

[3] In response to F07, we make three points.

[4] 1. F07 states that the SLVsteric signal in G06 is an overestimate. We thus made a revision of the program used to estimate that signal and did identify a wrong line in our code. Once it was corrected, we obtained a similar signal to that in F06. We thank F07 for pointing out the discrepancy.

[5] 2. Both G06 and F06 use the same monthly GRACE data, namely the Release 01 (RL01) of level-2 CSR GRACE gravity fields between April 2002 and July 2004, and apply the same treatment to the data in relation to the nontidal barotropic ocean correction, and degree-1 and degree-2 spherical harmonics. However, there are three main differences in estimating the average SLVmass over the Mediterranean: (1) the radius and the truncation degree used in the averaging Gaussian filter [*Swenson and Wahr*, 2002]; (2) the spectral leakage in SLVmass produced by water mass variations in the Mediterranean surrounding areas; and (3) restoration of the diminution of the SLVmass signal produced by the Gaussian filter. We address them in inverse order, as follows.

[6] The Gaussian filter diminishes the amplitude of the averaged signal. F06 restored that diminution according to the algorithm of *Velicogna and Wahr* [2006], which unfortunately was not yet published when G06 was accepted for publication.

[7] Spectral leakage is a main theoretical extension of F06 over G06, and obviously a justified improvement.

[8] High-degree SH coefficients from GRACE are contaminated by noise [e.g., *Tapley et al.*, 2004; *Wahr et al.*, 2004; *Swenson and Wahr*, 2006], and then, an averaging Gaussian filter is used to reduce their contribution [*Swenson and Wahr*, 2002]. The averaging Gaussian filter depends on a radius, *r*. G06 uses r = 1000 km and SH coefficients up to degree 15, and F06 uses r = 400 km and SH coefficients up to 90. F07 states that filter in F06 is more appropriated than the one in G06. However, we do not agree with this statement. Figure 1 shows than both filters produce almost

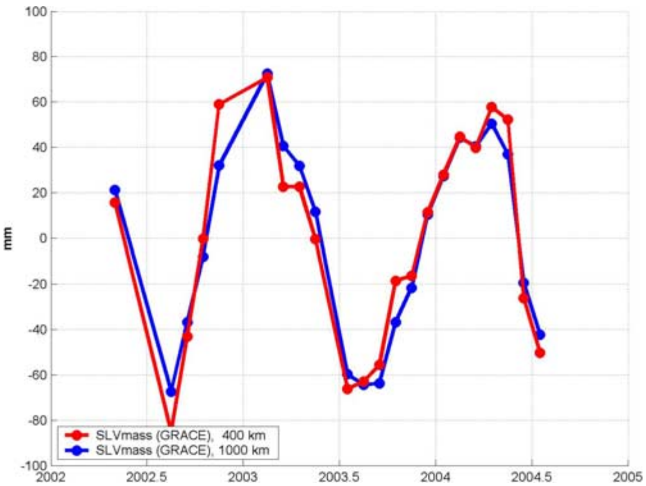

Figure 1. Average Gaussian filtered GRACE SLVmass over the Mediterranean Sea using two radii, r = 400 km (red line) and r = 1000 km (blue line).

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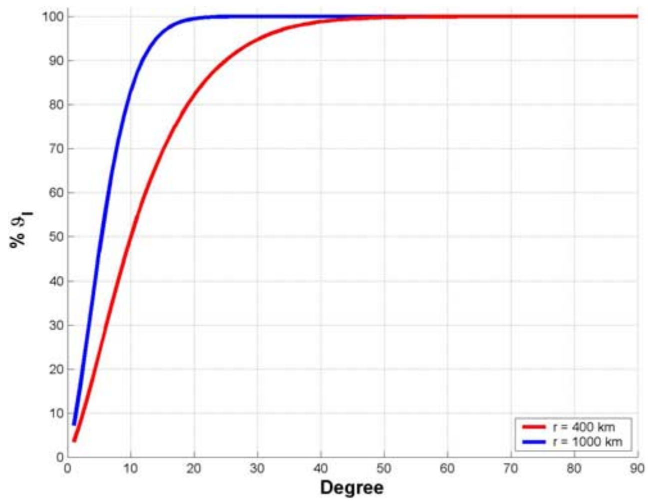

Figure 2. Percentage of the accumulative amplitude spectrum, as a function of degree, of the averaging Gaussian filters in the Mediterranean Sea using r = 1000 km (blue line) and r = 400 km (red line).

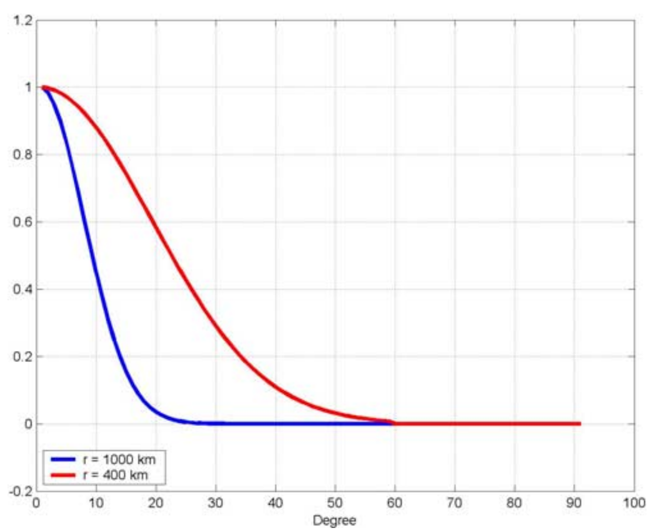

Figure 3. Weight of the SH coefficients when a Gaussian filter is applied for two radii: r = 400 km (red line) and r = 1000 km (blue line).

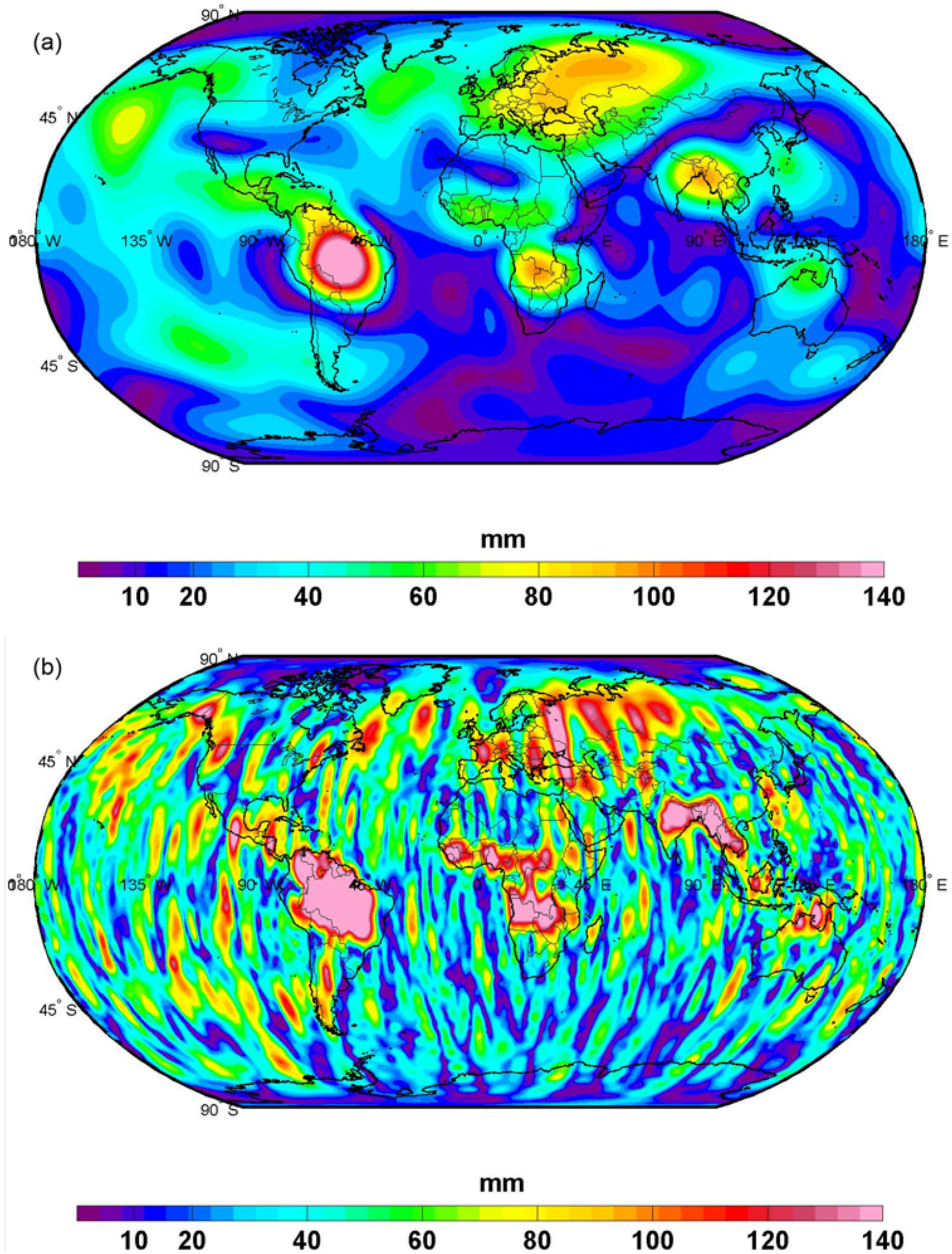

Figure 4. Annual amplitude of the GRACE-deduced mass variations. SH coefficients have been Gaussian filtered with two radii: (a) r = 1000 km and (b) r = 400 km.

exactly the same signal. The reason is found in Figure 2, which shows the percentage of the accumulative amplitude spectrum, as a function of degree, of the averaging Gaussian filters in the Mediterranean Sea using r = 1000 km (blue line) and r = 400 km (red line). The truncation at degree 15 in G06 accounts for the 95% of the signal and then it is not relevant. In the case of F06 the use of SH coefficients of degree further 50 is completely useless.

[9] The election of the radius seems not to be very important when applying an averaging Gaussian filter in the Mediterranean Sea. However, when a spatial averaging is not concerned, a Gaussian filtering with r = 1000 km is much more convenient than with r = 400 km. The Gaussian filter weights the SH coefficients as shown in Figure 3, for r = 400 km (red line) and r = 1000 km (blue line). RL01 CSR GRACE SH coefficients are sufficiently well determined up to degree $\sim$15 [*Tapley et al.*, 2004; *Wahr et al.*, 2004]. When r = 1000 km is used, SH coefficients between degree 15 and 25 have a very small contribution, and those of degree greater than 25 are virtually zero. However, SH coefficients of degree >15, which are already within the range of the noisy SH coefficients, contribute a lot when r = 400 km is used. Figures 4a and 4b show the annual amplitude of GRACE-deduced mass variations using radius of 1000 km and 400 km, respectively, to Gaussian filter the SH coefficients. The resulting map in Figure 4a shows recognizable signals as those of Amazon basin or the Monsoons. Figure 4b shows unrealistic north-south stripes,

which have been related to errors in high-degree SH coefficients [*Swenson and Wahr*, 2006].

[10] 3. The monthly water mass flux in the Mediterranean can be obtained by simply subtracting the water mass of two consecutive months from the GRACE data. However, GRACE data used in G06 and F07 had gaps between April 2002 and July 2004, in particular, June 2002, July 2002, December 2002, January 2003 and June 2003 are missing. Therefore only 18 monthly flux can be recovered. On the other hand, although F06 states that 20 monthly GRACE data are used, their Figures 3 and 4 show 25 monthly data. We do not know the origin of those extra points and cannot comment on the differences.

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